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TORQUE MEASUREMENTS OF GREASE-LUBRICATED COTTON PICKING UNITS[1/]

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INTRODUCTION

Picking units on a gear-driven spindle cotton picker have as many as 560 spindles per row. These spindles rotate at a maximum speed of 2,650 revolutions per minute. External forces are applied to the spindles by the seed cotton, doffers, and moistener pads. Spindles are mounted in vertical bars and are driven by gears rotating inside the bars against gear teeth on the spindle. These precision parts must be properly lubricated to operate with low maintenance and without excessive power requirements. The viscosity of the lubricant must be such that it cannot flow past the seals and contaminate the cotton[3/], yet it must not cause excessive starting torque when used in cold weather.

Grease-lubricated picker bars are generally lubricated at 20-hour intervals. Oil-lubricated picker bars are usually lubricated each day. Grease is applied through a fitting near the top of the bar and penetrates the whole length of the bar when parts inside are rotated. A special spindle gear lubricant is used in the bars; other parts of the machine are lubricated by use of a multipurpose grease.

In cold weather the picking unit is difficult to start in rotation, especially when it has just been greased. The slip clutches are often ruined or the drive belts are stretched while trying to rotate the unit. To determine the magnitude of the torque and to investigate the grease properties that cause high torque, power measurements were made for 2 years during periods of cold weather.[4/]

1/ The research was a cooperative investigation between the Agricultural Engineering Research Division, Agricultural Research Service, U.S. Department of Agriculture, and Mississippi Agricultural Experiment Station, Delta Branch, Stoneville, Miss., and is a contribution to Regional Cotton Mechanization Project S-2.

2/ Agricultural engineers, Agricultural Engineering Research Division, Agricultural Research Service, U.S. Department of Agriculture.

3/ Parker, R. E., et al. Oils used as mechanical picker spindle moisteners may affect cotton's quality. Miss. Agr. Expt. Sta. Inform. Sheet 774. August 1962.

4/ Appreciation is expressed to personnel of the Baton Rouge Refinery, Humble Oil and Refining Company, for assistance in selecting greases, furnishing equipment and making laboratory tests.

DESCRIPTION OF TEST

Torque measurements were made on both picking units of an International Harvester[5/] 220-A two-row high-drum picker. Two Baldwin-Lima-Hamilton type A, SR-4 strain gage torque pickup units were used. They were of 0- to 5,000-inch-pound capacity with a recommended input of 12 volts and a maximum input of 25 volts.

Power was supplied to the torquemeters with a 12-volt wet-charge battery. Four 350-ohm strain gages were mounted in the torque pickup, and it produced a 1.5 millivolt output per volt input. The torquemeter contained a temperature-compensating gage.

The torquemeter outputs were recorded with two Minneapolis-Honeywell Brown strip chart recorders. One was model Y153 X 12; the other, model Y153 X 18. These recorders were modified to obtain a 1-second full-scale response, to obtain speeds of 2, 4, 6, or 8 inches per minute, and to record a 0- to 18-millivolt range. The maximum output of the torque meters was 18 millivolts when a 12-volt input was applied.

A Minneapolis-Honeywell 16-point recorder was used to record temperatures during the test. Containers of grease were stored outdoors, and thermocouples were placed in each container to record the grease temperature. Thermocouples were also placed in each picker drum and near the picker to record ambient air temperature.

The torquemeters were mounted in the picking unit drive shaft that connects the transmission to the picker drum gear box. They replaced the slip clutches and were attached in the drive shaft by two Browning FS5H flexible couplings (Fig. 1). To hold the flexible couplings together, the telescoping section of the shaft was used with a spring that pressed against the end.

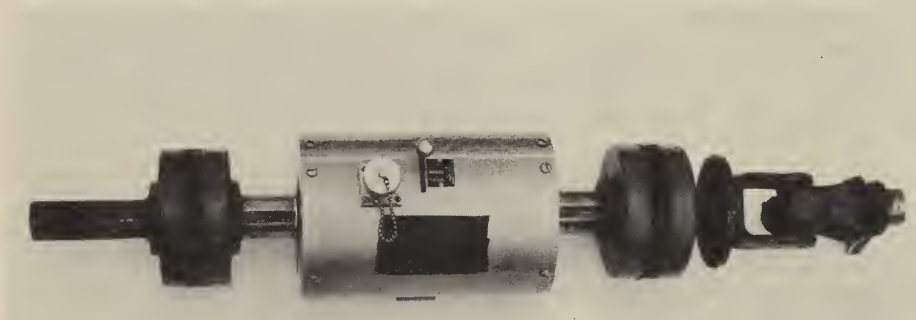

Figure 1. Baldwin-Lima-Hamilton SR-4 torque pickup unit mounted in picker drive shaft.

5/ Mention of a producing firm and products does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned. They are used in this publication solely for the purpose of providing specific information.

Torquemeters were installed by lowering the picking units, putting the flexible couplings together, and raising the units slightly to put tension on the springs. The picking units were secured in this position during the entire test to prevent variations in strain caused by the alinement of the universal joints.

A method of cleaning the grease from the bars was developed by using the oil-lubrication system that originally was on the International Harvester picker. This picker had subsequently been converted to a grease-lubrication system. Grease that hardened in the bars after field use could not be completely dissolved, so the bars were at first removed and cleaned by hand. In using the original oil-lubrication system, toluene was used to flush the grease from the bars between tests. This solvent was put in a 2 1/2-gallon paint tank under 20 p.s.i. pressure and fed by hose to the top of each picker rotor where the oil lubricant normally enters. The bottom spindle in each bar was removed to allow the solvent to flow through the bars more easily.

After the completion of each test, about 2 1/2 gallons of solvent was flushed very slowly through the bars. When the solvent had penetrated the grease for 30 minutes, an additional 12 1/2 gallons was flushed through the bars while the picker drums were rotated at various speeds. At first the drums were turned slowly; then they were turned at maximum speed to sling out the grease and solvent from the spindles and the bottoms of the bars. The bottom spindles were cleaned by hand and then put back in the machine. Bars were allowed to dry before regreasing.

Grease was applied to the bars through a fitting below the fifth spindle from the top until grease began coming out at the bar caps at the top of the bars. When this occurred, greasing was stopped. The machine was then operated at full throttle for 6 minutes to allow the grease to flow to the spindles and to the bottom of the bar. Some of the lower spindles were removed as a spot check to determine if grease had reached the lower part of the bar. For some tests, additional grease had to be packed around the lower spindles by hand. The flushing and greasing procedure used in this study did not allow all voids in the bars to be filled with grease, as could be done by hand packing. However, the lubrication procedure results were very close to those obtained during regular field servicing.

TEST PROCEDURE

When lubrication was completed, the picker was checked for proper operation and the electrical cables were connected between the picker outside the building and the recorders inside the building. Torque was measured when the desired ambient air temperature was obtained and the grease temperature had reached equilibrium with the air. Instruments for recording the torque were calibrated before and after each test by the use of a calibrating resistor.

The picker engine was allowed to reach operating temperature, and then the picking units were put in motion by releasing the clutch with the engine at half throttle. Shortly after the clutch was released, the throttle was moved to the maximum setting. The International Harvester 220-A picking units were operated in first picking speed with the drive shaft turning 600 r.p.m. and the spindles turning 2,020 r.p.m. Each test was continued until the torque became practically constant (Fig. 2). The total running time test for most greases was about 33 minutes.

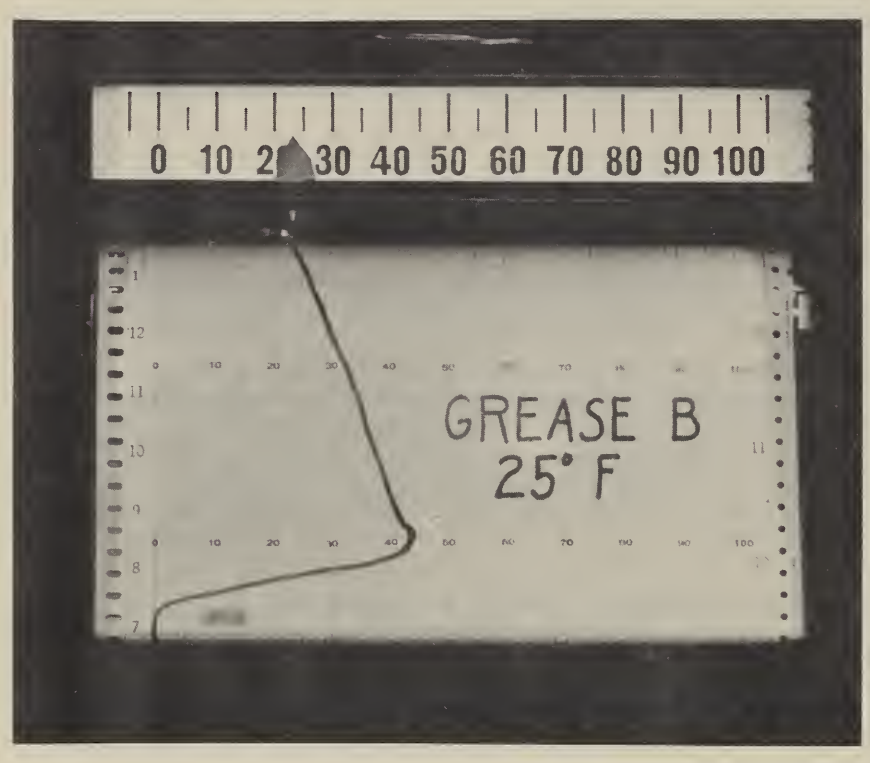

Figure 2. Strip chart recorder used to measure starting and running torques in cold weather. Tracing on chart illustrates high torque when clutch was released and constant decrease as lubricants in picker warmed.

PRELIMINARY TESTS

Torque measurements on a 20-spindle picker bar were made in cooperation with Humble Oil Company. This bar was hand packed with grease and mounted in a refrigerated chamber. Torque measurements were made on the spindle drive gear at temperatures of 25°, 45°, and 65° F. Starting and running torques were recorded for seven experimental greases.

1962 TESTS

Ten greases were tested in 1962 on the two-row picker. Features and properties of greases used throughout the tests are shown in table 1.

Table 1. Properties of grease used in picker head torque experiment, Stoneville, Miss., 1961-62[1/]

Grease features	Properties of greases									
	A	B	C	D	E	F	G	H	I	K
Color	Green	Green	Green	Green	Buff	Blue	Li. Buff	Li. Tan	Brown	Green
Soap----------type	Li/Ba	Li/Ba	Ca	Ca	Li/Ca	Ca	Ca	Li/Ca	Li/Ca	Li
Soap content (ASTM D-128---------percent	4.0	4.0	3.2	10.2	4.5	4.3	4.3	8.3	6.4	4.0
Base oil viscosity at 100° F. (ASTM D-455 and 446)[2/] S.U.S.-----	109	111	64	109	151	119	102	105	105	111
Worked penetration at 19-20° F. (ASTM D-217) ----------0.10 mm.	368	406	375	309	341	313	366	344	403	365 (at 32° F.)
Apparent viscosity, (ASTM D-1092) at 0°F.:										
15.7 reciprocal seconds per poise-----	188	188	135	377	377	377	215	215	282	--
62.6 reciprocal seconds per poise-----	90	80	53	93	93	93	67	93	93	--
135.0 reciprocal seconds per poise-----	44	44	32	44	44	44	44	44	46	--
Apparent viscosity, (ASTM D-1092) at 20°F.										
15.7 reciprocal seconds per poise-----	135	121	81	377	350	353	80	175	135	--
62.6 reciprocal seconds per poise-----	57	43	37	93	93	93	43	63	53	--
135.0 reciprocal seconds per poise-----	38	30	22	44	46	44	30	41	35	--

1/ Greases and information on properties furnished by Humble Oil and Refining Company, Baton Rouge, La.
2/ S.U.S. means Saybolt Universal Seconds.

Since the ambient air temperature was the factor that determined when a test was made, torque measurements could not be made at 25° F. for five of the greases during the winter of 1962. Unless otherwise indicated, the temperatures were within ±5° F. of the test goal.

The initial torque, starting torque, and running torque at 3 temperatures for the 10 greases used in the 1962 tests are shown in table 2. Initial torque was the peak torque recorded when the clutch was engaged. It was influenced somewhat by the manner in which the clutch was released. Starting torque was the reading at the time the picking unit attained operating speed. Running torque was the torque at the end of 26 minutes of operation.

Using grease K as an example, initial rotation and starting and running the unit required 18.2, 15.7, and 6.8 horsepower, respectively, at 25° F. These figures were reduced to 14.5, 13.6, and 5.4 horsepower at 45° F. and to 10.7, 7.8, and 5.2 horsepower at 65° F. At all temperatures, the running torque was nearly the same at the end of 26 minutes.

Observations while greasing the machine indicated that greases E and D were considered thick, penetrated the bars slowly, and lubricated a dry bar poorly. Greases F and H were of medium consistency, penetrated faster, and apparently gave better lubrication. The bottom spindles in some bars were getting hot when using greases D and H.

All other greases were considered thin, penetrated the bars rapidly, and provided good lubrication. These greases slung out around the spindles much faster than the others. At low temperatures grease C required less torque because it is low in viscosity and has a low soap content. There was too much variation among the other greases to single out the properties causing high torque.

1963 TESTS

Only five greases were used in tests at 32° F. or lower in 1963. Greases B, C, G, I, and K, the properties of which are described in table 1, were tested in 1963. These greases were selected from the original 10 because of their dissimilar properties. They included both single- and mixed-base soaps. Soap contents of these greases ranged from 3.2 to 6.4 percent; base oil viscosities, from 64 to 111 S.U.S. at 100° F.; worked penetrations at 19° - 20° F., from 366 to 406 tenths of millimeters; and the apparent viscosities covered a wide range.

Table 2. Initial, starting, and running torque measurements on a picking unit, Stoneville, Miss., 1962[1/]

Grease	Temperature	Torque[2/]		
		Initial	Starting	Running
	Degrees F.	Inch-pounds	Inch-pounds	Inch-pounds
A----	45	1,843	1,431	703
	65	1,939	786	367
B----	65	977	741	489
C----	3/ 33	1,601	1,208	551
	45	1,554	844	518
	65	1,706	893	578
D----	3/ 33	1,252	1,153	675
	45	1,322	919	677
	65	1,271	929	587
E----	45	1,452	1,186	666
	65	1,833	873	640
F----	45	1,029	900	530
	65	1,353	726	594
G----	45	1,534	1,081	591
	65	1,324	828	591
H----	25	2,239	1,713	711
	45	1,105	878	662
	65	1,545	866	768
I----	3/ 39	1,313	1,103	761
	45	1,240	1,022	519
	65	975	708	440
K----	25	1,914	1,650	709
	45	1,528	1,430	569
	65	1,122	816	544

1/ International Harvester 220-A high-drum picker.
2/ Most of these data represent only one replication.
3/ 25° F. temperature could not be attained. Other test temperatures are within ±5° F. of the stated temperatures.

At least three replications of the torque measurements were made for each grease, although the temperatures at the time of the tests ranged from 4° to 32° F. The total running time for each test was 33 minutes. The initial torque, starting torque, and running torque for these five greases at stated temperatures are shown in table 3. The temperature of 4° F. would rarely be encountered in field practice, but the other temperatures may be encountered when picking is delayed because of wet fields. It is then an advantage to pick cotton when the ground is frozen.

Table 3. Initial, starting, and running torque measurements on a picking unit, Stoneville, Miss., 1963[1/]

Grease	Temperature	Torque[2/]		
		Initial	Starting	Running
	Degrees F.	Inch-pounds	Inch-pounds	Inch-pounds
I----	4	3,868	3,713	1,017
	12	2,855	2,551	866
	22	2,894	2,486	908
B----	4	2,660	2,548	1,050
	12	2,512	2,356	877
	22	2,341	2,043	918
K----	16	2,811	2,602	838
	20	2,242	2,174	747
	32	2,010	1,763	667
G----	20	1,949	1,861	820
	26	1,870	1,687	677
	32	1,658	1,478	806
C----	18	1,927	1,467	548
	20	1,784	1,262	446
	30	1,221	1,043	666

1/ International Harvester 220-A high-drum picker.
2/ Measurements represent one replication.

The average weight of grease added to each bar in these tests was approximately 277 grams, compared with an average of 311 grams added in the single-bar tests when the bar was packed by hand (table 4). The lower spindles gave

Table 4. Quantity of grease applied to picker bars when lubricated before each test, Stoneville, Miss., 1962 and 1963 1/

Year of test and grease symbol	Left head				Right head			
	Outside rotor		Inside rotor		Outside rotor		Inside rotor	
	Per rotor	Per bar	Per rotor	Per bar	Per rotor	Per bar	Per rotor	Per bar
	Pounds	Grams	Pounds	Grams	Pounds	Grams	Pounds	Grams
1962:								
A------	--	--	--	--	4.75	153.9	4.25	160.7
A------	--	--	--	--	7.25	234.9	8.50	321.3
B------	9.25	299.7	7.75	292.9	--	--	--	--
C------	--	--	--	--	8.00	259.2	7.50	283.5
D------	9.50	307.8	6.75	255.2	--	--	--	--
E------	--	--	--	--	9.0	291.6	9.25	349.7
F------	8.25	267.3	7.75	292.9	--	--	--	--
G------	--	--	--	--	4.75	153.9	3.75	141.8
H------	7.75	251.1	7.00	264.6	8.00	259.2	6.00	226.8
I------	7.00	226.8	7.00	264.6	9.00	291.6	8.25	311.9
I------	8.50	275.4	9.50	359.1	--	--	--	--
K------	10.00	324.0	8.50	321.3	--	--	--	--
K------	8.25	267.3	8.50	321.3	--	--	--	--
1963:								
B------	9.0	291.6	10.0	378.3	--	--	--	--
B------	9.0	291.6	8.0	302.7	--	--	--	--
C------	7.0	226.8	7.0	264.8	8.0	259.2	6.0	227.0
G------	9.0	291.6	6.0	227.0	--	--	--	--
G------	9.0	291.6	8.0	302.7	--	--	--	--
G------	7.0	226.8	7.0	264.8	--	--	--	--
I------	--	--	--	--	9.0	291.6	8.0	302.7
I------	--	--	--	--	8.0	259.2	8.0	302.7
K------	--	--	--	--	8.0	259.2	9.0	340.5
K------	--	--	--	--	14.0	453.6	8.0	302.7

1/ International Harvester 2-row high-drum machine. Outside rotor contained 14 bars; inside rotor, 12 bars.

no trouble by getting hot in the 1963 tests as they did in 1962. This may be attributed to the grease having penetrated all parts in the bars at the colder temperatures before spindles became hot. It may also be attributed to a change in the greasing procedure. In the 1963 tests, the grease was warmed to 65° F. before the bars were greased, whereas in the 1962 tests the grease remained outdoors until shortly before greasing time. The coldness of the grease may account for the fact that an average of 267.7 grams of grease was put into the bars in 1962 and 289.0 grams was applied in 1963.

The average picking unit torques when lubricated by the five greases tested in 1963 are shown in figure 3. The starting torque is plotted on the ordinate at zero time and is the beginning of the curve. Grease I caused the highest initial and starting torques (3,160 and 2,857 inch-pounds, respectively); grease B had the highest running torque at the end of 33 minutes. Grease I had the highest soap content (6.4 percent); greases B, G, and K contained about 4.0 percent soap. Grease C had the lowest starting and running torques, a lower soap content, and a lower viscosity than the other greases.

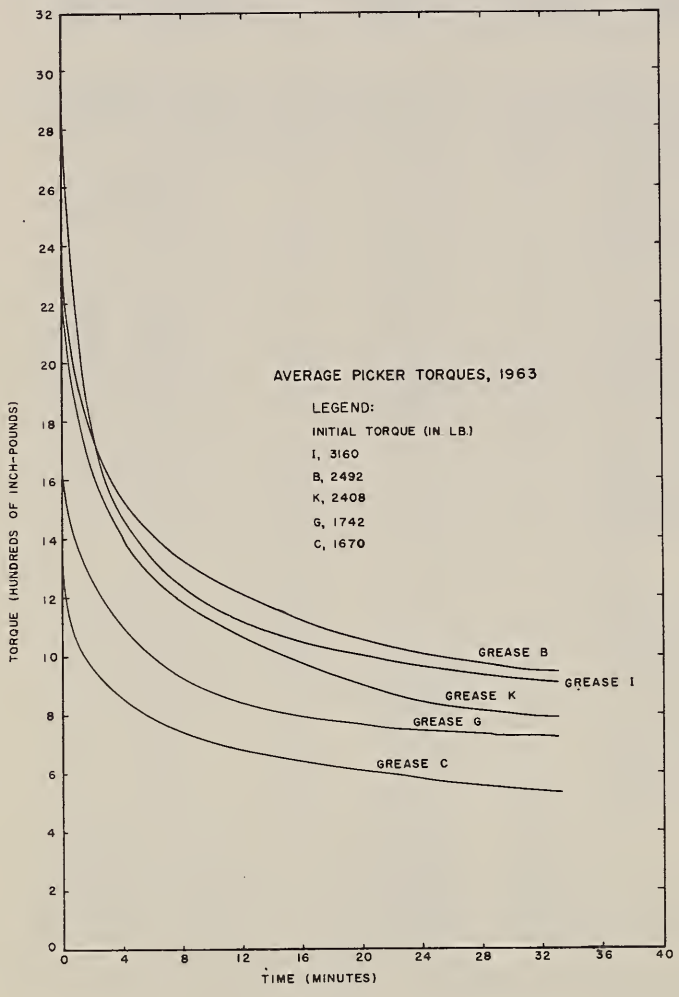

Figure 3. Average picker torques at temperatures below freezing, 1963 tests of greases B, C, G, I, and K.

Torques for greases I and K are plotted for three temperatures in the range at which tests were made (Fig. 4). The initial torque of 3,868 inch-pounds, recorded for grease I at 4° F., required approximately 37 horsepower to rotate one picking unit. The torque might have been higher had there been sufficient engine power to cause faster rotation. The engine on this picker developed a maximum of 70 brake horsepower. It is interesting to note that the shape of the torque curve is very similar for a given grease (Fig. 5). The curve merely shifts upward as the temperature is lowered and the grease gets thicker. At the coldest test temperatures, the torque dropped very fast after the unit was started. At the end of 3 minutes, torque was reduced by 50 percent. These variables for grease I are illustrated in figure 5.

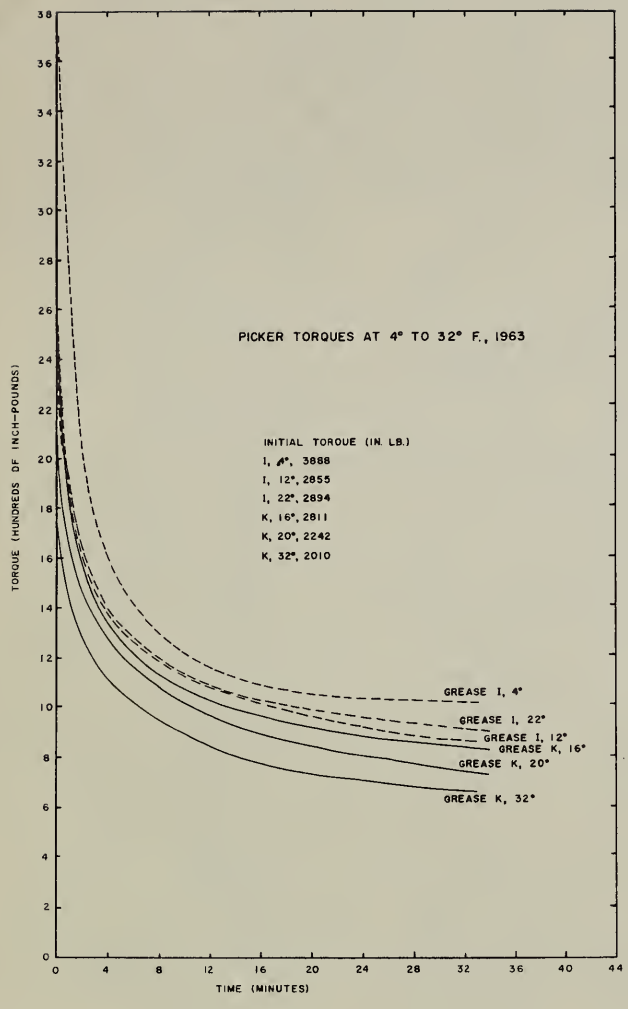

Figure 4. Picker torques for grease I and K at stated temperatures, 1963 tests.

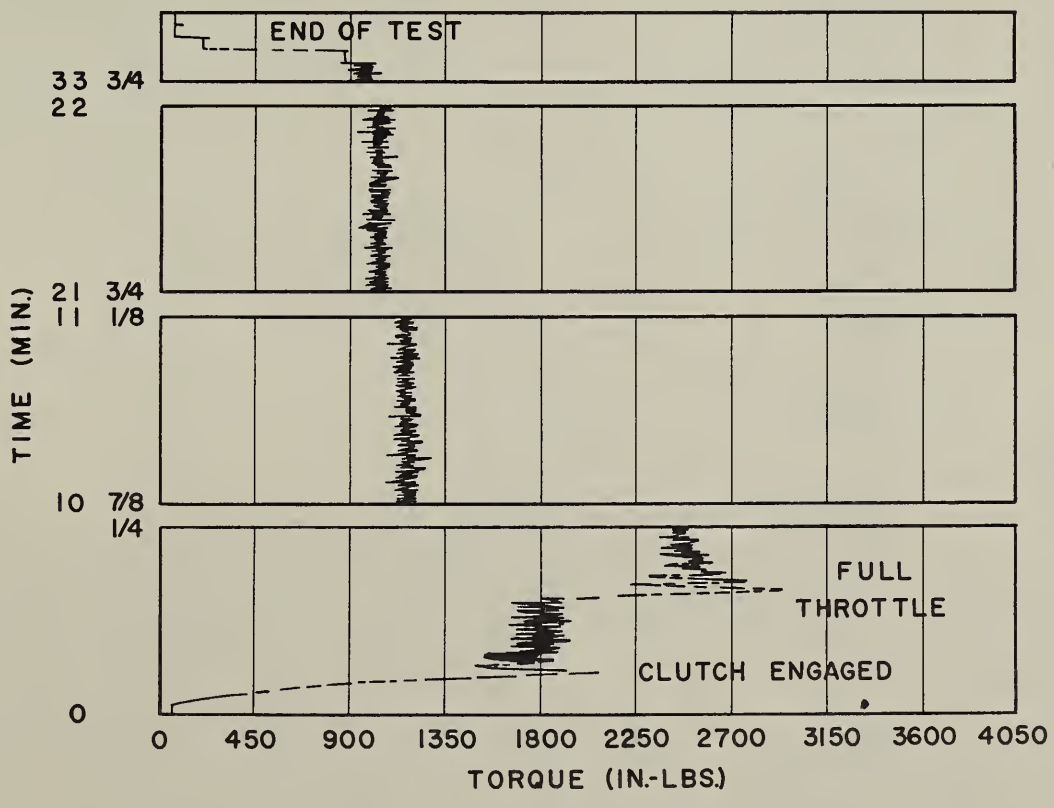

Figure 5. Changes in picker torque for grease I at stated temperature, 1963 tests.

Some of the additional torque brought on by cold weather was caused by stiffness of the gear-box lubricant and the lubricant used for other parts in the picking unit. An attempt was made to obtain a torque measurement in cold temperatures without grease in the bars. The torque measured was so high that the flexible couplings separated, and measurements could not be made even though there was solvent in the bars. This observation and the fact that a hot-running bar has higher than usual torque make it evident that extremely high friction occurs when a bar is not properly lubricated.

CONCLUSIONS

Measurements were made of the torque required to turn a high-drum cotton picking unit at various temperatures. A measured 37 horsepower was needed to start the unit rotating at 4° F. when lubricated by a grease with a lithium-calcium soap content of 6.4 percent and a base oil viscosity of 105 S.U.S. Another grease with a calcium soap content of 3.2 percent and a base oil viscosity of 64 S.U.S. required only 18.3 horsepower at 18° F. These two greases (I and C) used 9.7 and 5.2 horsepower, respectively, to keep the unit turning after 33 minutes operation. Apparently, soap content and viscosity have a great effect on starting and running torques.

Grease I required 11 horsepower less to start the unit rotating at 22° F. than at 4° F., and less horsepower was required to keep the unit running. Grease C required 6.7 horsepower less at 30° F. than at 18° F. A decrease in temperature changed the position of the torque curve, but curves are similar for a given grease.

The tremendous torques observed when gears were not lubricated stress the importance of proper lubrication. Many precision parts may be worn in a very short time by excessive friction. Some type of torque- or heat-indicating unit inserted in the drive shaft or in the bars could possibly help prevent costly repairs to spindle drives and prevent loss of picker time during the peak harvest season.

The difference in starting and running torques when greases of different types were used in the tests indicates that picker owners would save on costs if low-torque greases could be developed. The loss of grease around bushings and operating time between greasings are other factors that should be considered.

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